The Value of Thermal Energy – The BMC Microbrewery

Bill Brewmaster is a production manager at BMC Microbrewery. The plant is currently being upgraded to include a new brew kettle to convert starches in a malt/grain solution to sugars. The process calls for a watery solution to be heated from 80^{o}F to 212 ^{o}F and boiled for one hour to concentrate the solution (about 10% of the water is evaporated). Elsewhere in the brewery process, a 850 ton mechanical chiller, currently driven by a 500 kW electric motor is used for part of the fermentation process. Bill had recently attended an energy efficiency conference where he learned that he might be able to reduce his energy costs and reduce the microbrewery's impact on the environment if he could install steam turbine drive instead of electric motor for the mechanical chiller. Bill's boss, Art E is an outspoken local businessman who is concerned about sustainable community issues and has expressed a strong interest in making the BMG Microbrewery a model of economic and environmental sustainability. Bill asked his engineering firm to take a closer look at the options for both the brew kettle and steam turbine and this is what they discovered.

Study Approach

The criteria for determining environmental impacts/benefits was agreed upon as the amount of primary energy needed to meet all the process requirements. The brewery purchases all of its electric requirements from the local electric utility and generates steam on site. To generate steam, the BMG Microbrewery already has an oversized 150 psig boiler that is used for building heat and steam cleaning beer bottles. Three options were evaluated as follows:

1) Use an electric resistance heating to heat the brew kettle while using the current electric motors to drive the chiller. This is an all-electric option.
2) Use steam from the existing boiler through heating coils to heat the brew kettle while using the current electric motor to drive the chiller. This is a combination thermal and electric option.
3) Use steam from the existing boiler through heating coils to heat the brew kettle and replace the electric motor with a steam turbine drive to operate the chiller. This is an all thermal option.

In order for the engineering firm to compare the various options, they first calculate how much energy the process will require for heating the brew kettle and driving the chiller.

Brewing Data:	The brew kettle has a capacity of 12400 gallons (equivalent to 40 barrels of beer)
	It takes 1000 Btu to evaporate one pound of the liquid solution at its boiling point
	It takes 1 Btu to heat one pound of the solution 1^{o}F

Brewing Calc: Heating the solution from 80^{o}F to 212 ^{o}F with 10% evaporation takes 23 MMBtu of energy:

Motor Data: The electric motor is 95% efficient operating at full load
The 500 kW motor requires 526 kW of electric demand .

Steam Turbine: A steam turbine converts thermal energy to mechanical energy by extracting energy from the steam as it lowers the steam pressure. Steam enters the steam turbine at 150 psig and exits at 15 psig. Based on the inlet and exit pressure, the steam turbine at 62% efficiency requires 42 lbs. of steam for every 1 kWh produced consuming 81 Btu of the energy per pound of steam as it drops in pressure through the turbine.

Boiler Data: Current boiler operates at 80% efficiency

Steam conditions of the boiler are 150 psig/ 373 ^{o}F. The steam has an energy content of 1200 Btu/lb as it leaves the boiler.

Evaluation of Various Options

<u>Option 1</u>

This option would use electricity to both heat the kettle and to drive the chiller motor:

<u>Motor</u>
Converting 526 kW of electric demand (3413 Btu/kWh) requires 1.8 MMBtu of electricity. Knowing that the average U.S. utility converts only 33% of its fuel input to electricity conversion, for the delivery of 1.8 MMBtu of electricity, approximately 5.5 MMBtu of fuel would be consumed in a conventional utility plant.

<u>Brewing</u>
We know from above brewing calculation that the brew kettle requires 23 MMBtu of energy. Although resistance heating is 100% efficient, inefficiency in the conversion of fuel to electricity from a conventional utility plant would still exist. Thus the total fuel energy required by the brew kettle is 69.7 MMBtu fuel.

Total fuel for Option 1 is **75.2 MMBtu**

<u>Option 2</u>

This option would use steam to heat the kettle and electricity to drive chiller motor:

Motor
The calculation is the same as Option 1 which is 5.5 MMBtu of fuel required.

Brewing
The brew kettle requires 23 MMBtu of energy delivered from a boiler which is 80% efficient. Therefore, the boiler will consume 28.8 MMBtu of fuel.

Total fuel for Option 2 is **39.7 MMBtu**

Option 3

This option would use steam to heat the kettle and to drive steam turbines connected to the chiller. The steam from the boiler would first be used to drive the steam turbine drives and then piped over to the brew kettle for heating. No electricity is required:

Steam Turbine
As we previously noted, the chiller requires 500 kW. The steam turbine requires 42 lbs of steam to be passed through it and it "consumes" 81 btu of energy per lb of steam that is passed through the turbine producing a kW of mechanical power. The steam is supplied by the boiler. The steam turbine would therefore consume 1.7 MMBtu of energy delivered from a boiler (which is 80 % efficient). Therefore, 2.1 MMBtu of fuel is needed.

Brewing:
The calculation is the same as Option 2 which is 28.8 MMBtu of fuel required.

Total fuel for Option 3 is **30.9 MMBtu.**

Conclusion

As the engineering analysis shows, option three requires the least amount of fuel and would thus have the least impact on the environment. The summary table below shows the expected emissions of NOx of each case if the boiler used to produce the electricity or the steam had an emissions rate of 0.15 lb NOx/MMBtu of fuel for 8000 hours per year.

Option	Electric	Steam	Total Fuel (MMbtu per hour)	NOx Emissions (tons per year)
# 1	Brewing and motor		75.2	45.1
# 2	Motor only	Brewing only	39.7	23.8
# 3		Brewing and motor	30.9	18.5